The impact of Stress and Anxiety on the neurocognitive performance of Australian Nurses:

An electroencephalographic and psychometric assessment

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I. Declaration

I certify that the work in this thesis has not been previously submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature: Production Note: Signature removed prior to publication. Date: 12/07/2018

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III. Publications and Presentations

Publications relevant to thesis

Journal Articles

1. Maharaj, S., **Lees, T.,** and Lal, S., 2018. Negative Mental States and Their Association to the Cognitive Function of Nurses. *Journal of Psychophysiology*, doi: 10.1027/0269-8803/a000223
2. **Lees, T**., and Lal, S., 2017. Stress and its impact on the cognitive performance of Australian nurses. *Stress and Health*, **33**(1), 45-54 doi: 10.1002/smi.2672
3. **Lees, T**., Khushaba, R., and Lal, S., 2016. Electroencephalogram Associations to Cognitive Performance in Clinically Active Nurses. *Physiological Measurement*, **37**(7):968-980, doi: 10.1088/0967-3334/37/7/968

Conference Abstracts

1. **Lees, T**., Kalatzis, G., and Lal, S., 2015. Examining negative mental states and their association to psychometric and electroencephalographic measures of cognitive performance in Australian Nurses. *Psychophysiology*, **52**(S24), doi: 10.1111/psyp.12495
2. **Lees, T**., Maharaj, S., and Lal, S., 2015. Electroencephalographic markers of subjective cognitive performance: Implications towards electrophysiological prediction of early cognitive decline. *Frontiers in Human Neuroscience*. doi: 10.3389/conf.fnhum.2015.219.00057

Invited Presentations

1. **Lees, T**., Stress and Cognitive Performance in Nurses: An example of research in the NRU. Oral Presentation: Warfighter Effectiveness Research Centre (WERC) United States Airforce Academy Brownbag 2015, Colorado Springs, USA.

Conference Presentations

1. **Lees, T.,** Maharaj, S., Kalatzis, G., Nassif, N., Newton, P, and Lal, S. The neurocognitive relationship between stress and anxiety, and memory and decision making performance of Australian Nurses. Poster presentation: 58th

Annual meeting of the Society for Psychophysiological Research 2018, Quebec City, Canada

2. Maharaj, S., **Lees, T.,** Zaslawski, C., Fatima-Shad, K., and Lal, S. Assessing the link between negative mental states and cognitive performance in health professionals. Poster Presentation: 2017 Australasian Cognitive Neuroscience Society (ACNS) Conference, Adelaide, Australia.
3. Maharaj, S., **Lees, T**., and Lal, S., Electroencephalographic changes in beta & gamma reactivity associated with cognitive performance. Poster Presentation: Inter-University Neuroscience & Mental Health Conference 2016, Sydney, Australia
4. **Lees, T**., Kalatzis, G., and Lal, S. Examining negative mental states and their association to psychometric and electroencephalographic measures of cognitive performance in Australian Nurses. Poster presentation: 55th Annual meeting of the Society for Psychophysiological Research 2015. Seattle, USA
5. **Lees, T**., Maharaj, S., and Lal, S. Electroencephalographic markers of subjective cognitive performance: Implications towards electrophysiological prediction of early cognitive decline. Oral Presentation: 25th Annual Conference of the Australasian Society for Psychophysiology 2015, Sydney Australia
6. **Lees, T**., and Lal, S. Negative mental states, their association to frontal lobe brain activity and the effect coping. Oral Presentation: 2nd Inter-University Neuroscience & Mental Health Conference 2015, Sydney, Australia.
7. Maharaj, S., **Lees, T**., and Lal, S. Cognitive function associations to mental states in nurses. Poster presentation: 32nd Combined Health Science Conference; New Horizons 2015, Sydney, Australia.
8. Kalatzis, G., **Lees, T**., Nassif, N., and Lal, S. Investigating Cognitive Function in Clinical and Healthy Samples using Electroencephalography and Psychometric Assessment: A Comparative Study. Poster Presentation 32nd Combined Health Science Conference; New Horizons 2015, Sydney, Australia
9. **Lees, T**., and Lal, S. Electroencephalography and its associations to cognitive performance in nurses: An exploratory assessment. Poster Presentation: 30th Combined Health Science Conference; New Horizons 2013. Sydney, Australia.
10. **Lees, T**., and Lal, S. Occupational stress and cognitive performance in nurses. Poster Presentation: 29th Combined Health Science Conference; New Horizons 2012. Sydney, Australia.

Other Publications

Journal Articles

1. **Lees, T.,** Shad-Kaneez, F., Simpson, A.M., Nassif, N., Lin, Y., and Lal, S., 2018. Heart rate variability as a biomarker for predicting stroke, post-stroke complications and functionality. *Biomarker Insights* (In press)
2. **Lees, T**., Nassif, N., Simpson, A.M., Shad-Kaneez, F., Martiniello-Wilks, R., Lin, Y., Jones, A., Qu, X., and Lal, S., 2017. Recent advances in molecular biomarkers for diabetes mellitus: a systematic review. *Biomarkers*, 1-13, doi: 10.1080/1354750X.2017.1279216
3. Rothberg, L.J., **Lees, T**., Clifton-Bligh, R., and Lal, S., 2016. Associations between heart rate variability and blood glucose levels: implications for non-invasive glucose monitoring. *Diabetes Technology & Therapeutics*, **18**(6):366-376, doi: 10.1089/dia.2016.0010

Reports

1. Lal, S., **Lees, T**., Elliott, J.L., Rai, T., Gunning, S., and Newton, P., 2015. A review of current evidence about mental disorders and psychological and other wellbeing programs in the law enforcement workplace. Sydney, Australia. Commissioned by the NSW Police Force.

Invited Presentations

1. **Lees, T**., and Lal, S. Research and collaboration in the Neuroscience Research Unit (NRU). Oral Presentation: Warfighter Effectiveness Research Centre (WERC) United States Airforce Academy Brownbag 2015, Colorado Springs, USA.

Conference Presentations

1. Maharaj, S., **Lees, T.,** Zaslawski, C., Fatima-Shad, K., and Lal, S. The prevalence of depression in a cohort of Australian Nurses. Poster presentation: Inter-University Neuroscience & Mental Health Conference 2017, Sydney, Australia.
2. Kalatzis, G., **Lees, T.,** Nassif, N., Zaslawski, C., and Lal, S. Exploring cognitive function in diabetes and non-diabetes samples using electroencephalography

(EEG) and psychometric assessment: a comparative study. Oral presentation: 37th Annual Scientific Meeting of the Australasian Neuroscience Society 2017, Sydney, Australia

3. Hopkins, Z., **Lees, T.,** and Lal, S. Cardio vascular and Autonomic Associations to Post-traumatic stress disorder symptomatology. Oral Presentation: Inter-University Neuroscience & Mental Health Conference 2017, Sydney, Australia.
4. Vine, M., **Lees, T.,** Nassif, N., Simpson, A. M., and Lal, S. Investigating the associations between ADHD symptomology and chronic illness: cardiovascular disease and diabetes mellitus. Poster Presentation: Inter-University Neuroscience & Mental Health Conference 2017, Sydney, Australia.
5. Kalatzis, G., **Lees, T**., Nassif, N., Zaslawski, C., and Lal S. Investigating cognitive function in diabetes and healthy samples using electroencephalography (EEG) and psychometric assessment: a comparative study. Oral Presentation: Inter-University Neuroscience & Mental Health Conference 2016, Sydney, Australia
6. Jarman, L.R., Elliott J.L., **Lees, T**., Nassif, N., Simpson, A.M., Clifton-Bligh, R., and Lal, S. Associations between heart rate variability and blood glucose levels. Poster presentation: 33rd Combined Health Science Conference; New Horizons 2016, Sydney, Australia.
7. Ricciardiello, A., Elliott, J.L., **Lees, T**., and Lal, S. Emotion regulation and stress: physiological assessment. Poster presentation: 33rd Combined Health Science Conference; New Horizons 2016, Sydney, Australia
8. Gorval, M., **Lees, T**., Elliott, J.L., Nassif, N., Simpson, A.M., Clifton-Bligh, R., and Lal, S. Investigation of the association between blood glucose levels, anxiety and depression. Poster presentation: 33rd Combined Health Science Conference; New Horizons 2016, Sydney, Australia
9. Elliott, J., **Lees**, T., Nassif, N., and Lal, S. Stress and the New South Wales Police Force: The prevalence of various coping mechanisms. 2nd Inter-University Neuroscience & Mental Health Conference 2015, Sydney, Australia.
10. Kalatzis, G., **Lees, T**., and Lal, S. Investigating Cognitive Performance in Different Racial Groups: An Exploratory Study Using Electroencephalography and Psychometric Assessment. Poster presentation: 31st Combined Health Science Conference; New Horizons 2014. Sydney, Australia.

11. Elliot, J.L., **Lees, T.,** Nassif, N., and Lal, S. Cardiovascular measures and sleep health associations with shift work in police officers: A physiological assessment. Oral Presentation: 31st Combined Health Science Conference; New Horizons 2014. Sydney, Australia.

IV. Table of Contents

V. List of Figures

VI. List of Tables

VII. List of Equations

VIII. List of Abbreviations

A – Auricular

ACTH – Adrenocorticotropic hormone

AD – Alzheimer's Disease

AIN – Assistant in Nursing

AUD – Australian Dollars

AVP – Arginine vasopressin

BMI – Body Mass Index

BP – Blood pressure

C – Central

CRH – Corticotropin releasing hormone

DASS – Depression, Anxiety, Stress, Scale

EEG – Electroencephalography

EN – Enrolled Nurse

EOG - Electrooculogram

ERP – Event Related Potential

F – Frontal

Fp – Frontal Pole

GAD – Generalised Anxiety Disorder

HPA – Hypothalamic Pituitary Adrenal Axis

HR – Heart Rate

HREC – Human research ethics committee

IIR – Infinite Impulse Response

LAQ – Lifestyle Appraisal Questionnaire

LASSO – Least Absolute Shrinkage Selection Operator

mmHg – Millimetres mercury

MCI – Mild Cognitive Impairment

MMSE – Mini-mental State Exam

MRI – Magnetic Resonance Imaging

NHP – Non-health Professional

O – Occipital

OCD – Obsessive Compulsive Disorder

P – Parietal

PCA – Principal Component Analysis

PD – Panic Disorder

RN – Registered Nurse

SNS – Sympathetic Nervous System

SSI – Standard Shiftwork Index

T – Temporal

UTS – University of Technology Sydney

WCCL – Ways of Coping Checklist

IX. Abstract

Stress and anxiety both have demonstrable impact, causing neuronal damage and death (Sapolsky, 1996, Conrad, 2006), functional connectivity changes (Bishop, 2009, Andreescu et al., 2014), and various cognitive impairments (de Quervain et al., 2000, Savage et al., 2000, Wetzel et al., 2006, Henderson et al., 2012, Nieuwenhuys et al., 2015). However, despite demonstrated quality of care reductions (Sveinsdóttir et al., 2006, Berland et al., 2008) and calls for further research (LeBlanc, 2009, Lees and Lal, 2017), a limited amount of research investigating the impact of stress and anxiety on the cognitive performance of health professionals has been conducted (LeBlanc, 2009). Therefore, the aim of the present study was to examine the relationships between stress, anxiety and cognitive performance in health professionals via comprehensive psychometric and electroencephalography (EEG) assessment; as well as assess the predictive capability of EEG in measuring cognitive performance.

Presently, this doctoral research reports on results obtained by analysing data from 118 nurses and 144 non-health professionals. The experimental protocol commenced by capturing participant demographic data, such as, blood pressure, heart rate, as well as hip and waist measurements, followed by the completion of pre-study questionnaires including the Lifestyle Appraisal questionnaire (Craig et al., 1996), the Depression, Anxiety, Stress scale (Lovibond and Lovibond, 1995b), and the Fatigue State Question (Lal and Craig, 2002). Following this, a two lead bipolar or 32 lead monopolar EEG was captured during a resting baseline and a Stroop test based active phase. After the electroencephalogram recording, psychometric cognitive performance was assessed by the Mini-Mental State Examination (Folstein et al., 1975) and the Cognistat (Mueller et al., 2007). Participants then completed the revised Ways of Coping Checklist (Vitaliano et al., 1985), and the Fatigue State Question, again for the latter. Nurse participants also

completed parts of the Standard Shiftwork Index (Barton et al., 1995). Lastly, participant's blood pressure was again recorded and the experiment concluded.

The results indicate that both non-health professionals and nurses experience stress and anxiety. In both groups, a stress level within the normal range was significantly associated ($p < 0.05$) with increased memory performance and delta activity, while theta and beta activity increases were similarly implicated for the nurse group only. However, with an increase in stress levels, stress was associated with increased judgement performance and fronto-temporal and parietal gamma activity, as well as reduced fronto-temporal delta activity in non-health professionals. Additionally, impaired memory performance as well as fronto-central delta, fronto-temporal and parietal gamma, and fronto-central and temporal beta activity increases were associated with this increased stress in nurses.

With respect to anxiety, it was associated with increased lifestyle risk factors, impaired global, attention, and memory domain performance, as well as delta, alpha and gamma activity changes in non-health professionals. Comparatively, in nurses anxiety was associated with improved Stroop test performance, global cognitive performance and delta and gamma activity, as well as impaired memory performance. Lastly, it was found that global cognitive performance could be predicted by a combination of fast wave EEG activity variables ($R^2 \geq 0.440$; $p \leq 0.013$). Similarly, unique combinations of EEG variables from the 5 investigated frequency bands predicted, in varying degrees, attention ($R^2 \geq 0.204$; $p \leq 0.014$), memory ($R^2 \geq 0.443$, $p \leq 0.010$) and judgement ($R^2 \geq 0.407$; $p \leq 0.001$) domain performance.

Collectively, these findings provide an insight into the cognitive impact of stress and anxiety, and determine a unique impact profile of stress and anxiety for both non-health

professionals and nurses. Additionally, they demonstrate the multifaceted nature of the relationship between stress, anxiety and cognitive performance, where both improvements and impairments are observed. Further understanding the impact of stress and anxiety on cognitive performance may enable the development and implementation of management and intervention strategies to preserve the cognitive health of health professionals, and in turn, ensure quality of patient care and reduce adverse medical event incidence. Further, it may be possible to use EEG activity to predict early cognitive impairment, which has strong implications for developing diagnostic measures for cognitive impaired states such as dementia and Alzheimer's disease.